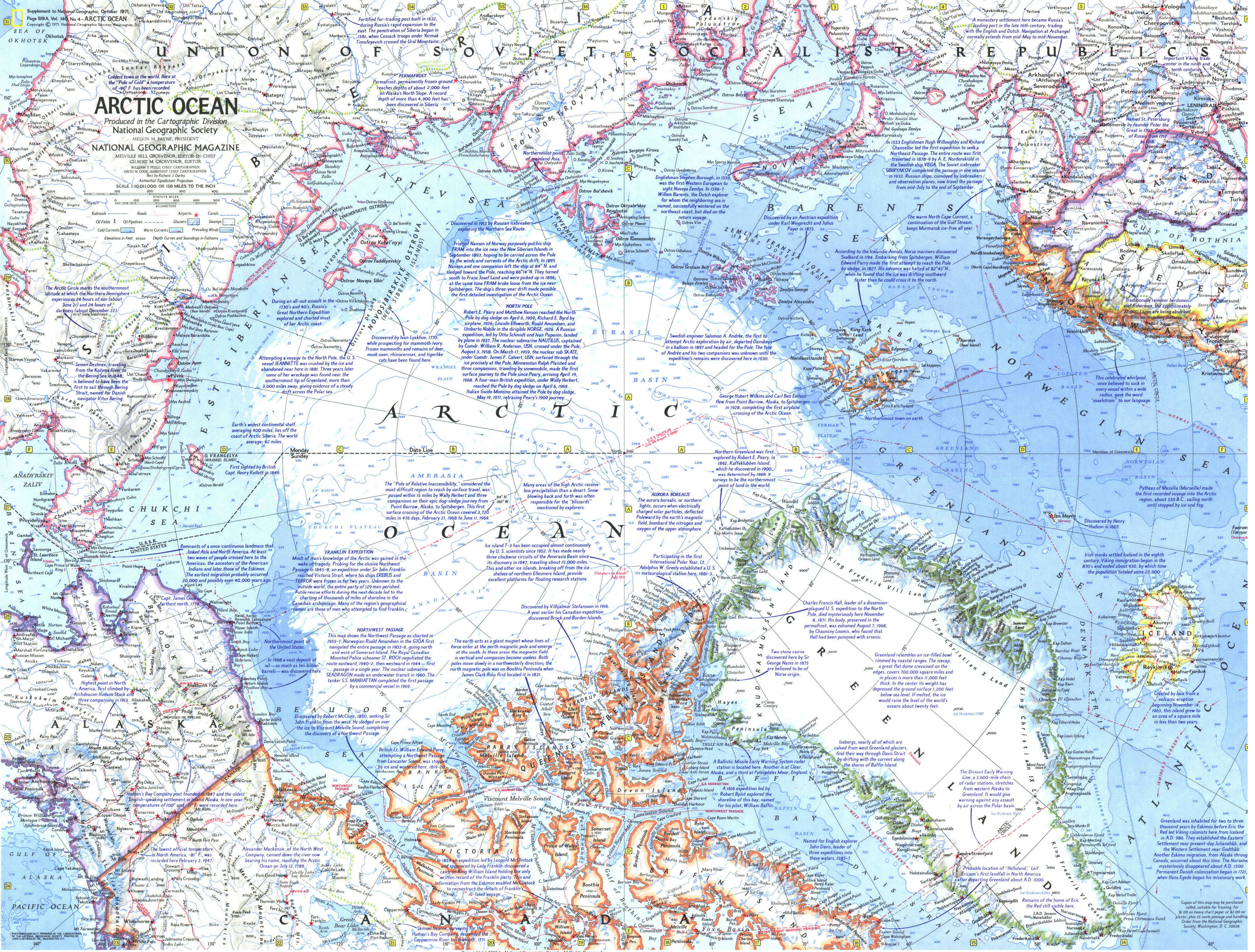

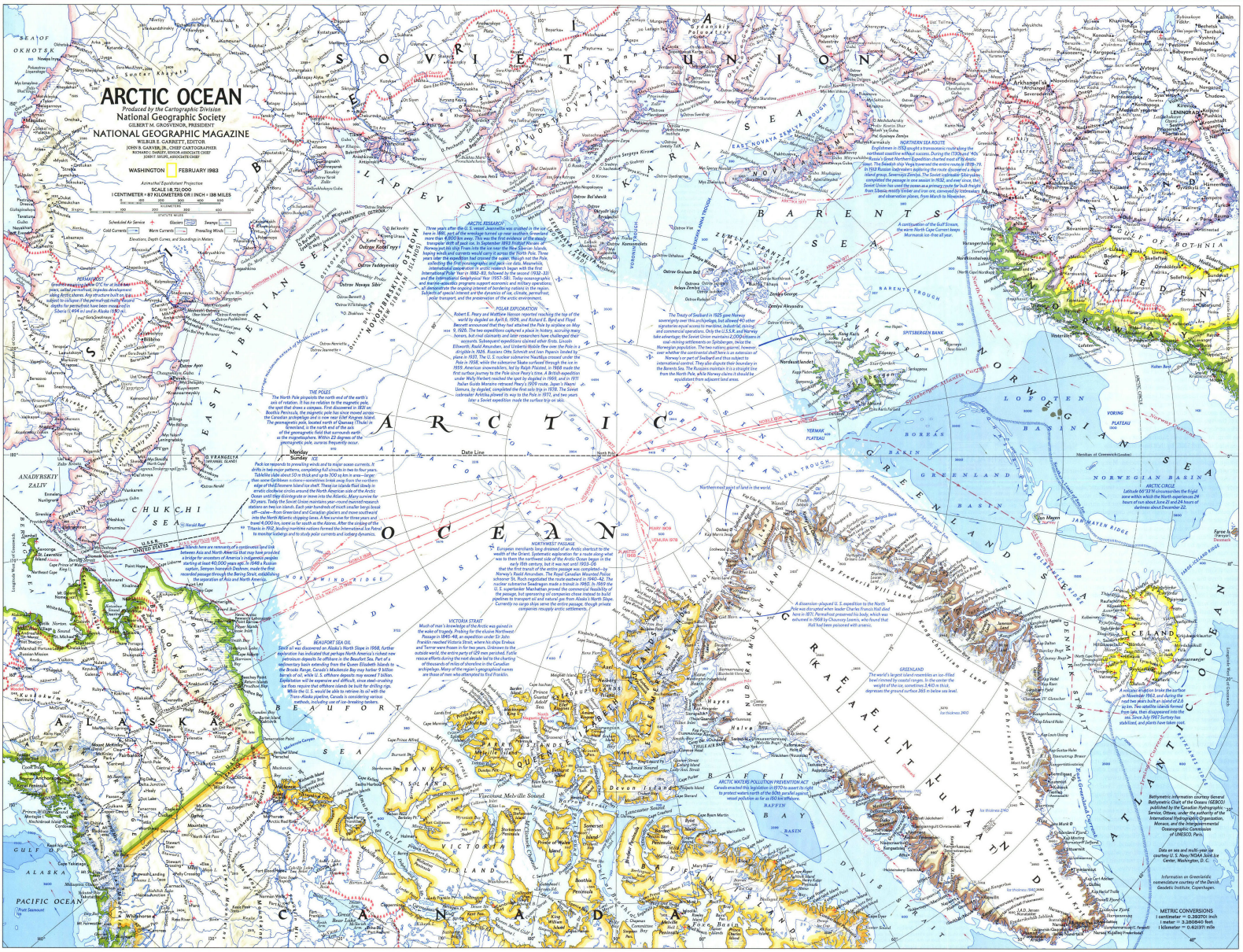

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WORLD OCEAN FLOORS Arctic Ocean

Produced by the Cartographic Division
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NATIONAL GEOGRAPHIC MAGAZINE
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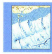
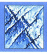
JOHN B. GARVER, JR., CHIEF CARTOGRAPHER
WASHINGTON, D. C., JANUARY 1990


CONTINENTAL MARGINS: Submerged land between coast and ocean basin, including the continental shelf, slope, and rise. The shallow, sunlit shelf waters host more marine life than any other ocean region.

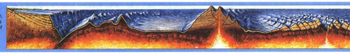

TRENCHES form when the ocean crust plunges beneath another crustal plate. The Mariana Trench in the Pacific is earth's deepest, nearly 11 kilometers below the surface.


SEAMOUNTS: Underwater volcanoes that rise at least a thousand meters above the seafloor. Those that penetrate the surface become islands, such as the Hawaiian chain.


ABYSSAL PLAINS: Extensive featureless regions of the ocean floor. Flattest surfaces on earth, these plains develop in areas of high sedimentation.


RIDGES: Underwater mountain ranges. The Mid-Ocean Ridge stretches 74,000 kilometers around the globe. Fracture zones cleave the ridge at right angles.

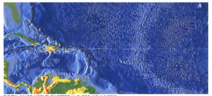
THE OCEAN CRUST constantly on the move reminds scientists of a slow-motion conveyor belt. In this composite view, magma rises up at a ridge (far right) as the seafloor moves toward the continental margin (far left) at an average rate of six centimeters a year. The heavier seafloor dives under the landmass and ultimately melts. Magma from an isolated hot spot (center) forms seamounts and islands.



Exploring and Mapping the Seafloor

Early mariners assumed the oceans to be bottomless—immense and mysterious realms inhabited by powerful gods and fantastic creatures. Ferdinand Magellan, pausing in 1521 in his voyage around the world, is said to have tossed spliced lengths of rope over the side and waited patiently for the end to hit bottom. Seeing that it did not, he proclaimed that the oceans were "immeasurably deep."

We chuckle at this today, but Magellan was right in his day. Accuracy has always been limited by technology. Confining themselves to coasts and harbors, early mariners were primarily concerned with ensuring that there was enough water beneath the ship's keel to prevent grounding. When the first regular charts were produced, they failed to depict the true shape and features of the seafloor. Indeed, it has only been within the past generation that large-scale maps of the ocean floors have been developed, and only in the past few decades that we have been able to measure these hidden landscapes with precision.



DIGITAL IMAGE (ABOVE) BY PETER W. SLOSS, NOAA/NGDC

The whole matter of ocean-bottom mapping took an abrupt turn in the 19th century when plans were made for the laying of the transatlantic telegraph cable. In the 1840s Matthew Fontaine Maury, head of the Navy's Depot of Charts and Instruments (now the Naval Oceanographic Office and the U. S. Naval Observatory), persuaded vessels plying the seas to send him reports on ocean conditions. In exchange he would send them his famous *Wind and Current Charts,* developed after systematic study of ships' logs kept in the depot's storerooms. At the same time, he instructed Navy vessels to record ocean depth soundings.

Maury's 1855 map (top) was an early bathymetric contour chart of the North Atlantic. The method that produced this chart—the leaded weight and sounding line—was both laborious and fraught with error. Yet it remained the best technology available until World War I.

The loss of *Titanic* in 1912 prompted the introduction of echo-sounding instruments. Later, sound navigation and ranging, or sonar, which bounces sonic waves off an object, was developed for underwater investigation, including detection of submarines.

After World War I, Harvey Hayes of the U. S. Naval Experimental Station in Annapolis, Maryland, invented the sonic depth finder. Before that breakthrough there existed only a single sounding for every 14,000 square kilometers of the Atlantic, and one for about every 26,000 square kilometers of the Pacific and Indian Oceans. Suddenly our information base exploded, and our impression of a flat and featureless seafloor changed dramatically. With newly discovered mountains, volcanic cones, vast canyons, and abyssal plains, the ocean bottom turned out to be as diverse as the land surface.

A major feature of Hayes's invention was its ability to have a ship take soundings without stopping. Any ship with a depth finder affixed to its hull could crisscross the ocean taking soundings, making it relatively easy to produce a profile of undersea terrain simply by "connecting the dots." The first bathymetric chart from such soundings appeared in 1923, and additional data were incorporated and published regularly afterward. The first contour map of the Arctic Ocean floor—ancestor to the one seen here—was made in 1958, when the submarine U.S.S. *Nautilus* cruised beneath the surface ice pack of the North Pole taking sonic readings.

During the 1960s two further breakthroughs took place. Scientists at the U. S. Naval Oceanographic Office transformed the single-beam echo technology into a multibeam system, generically dubbed swath or multibeam echo sounders. This allowed for an array of beams to measure depth in a swath nearly as wide as the water is deep (bottom, at left).

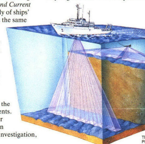
At the same time the British Institute of Oceanographic Sciences developed a long-range side-scan sonar imaging system, called GLORIA, that uses sound to produce images of geologic features. The instrument is towed (bottom, at right) behind a survey ship and records the strength and character of the echoes, producing an image of an expanse as wide as 60 kilometers. The results, coupled with depth data from the multibeam surveys, provided completely new views of the ocean-bottom landscape.

But more was coming. The next step was to measure the shape of the ocean surface from space. Gravity attracts water in areas where there are massive features. Mountains and ridges draw water toward them and cause bumps in the ocean surface; canyons and trenches cause depressions. Radar altimeters mounted on satellites are able to measure these subtle bumps and dips by bouncing microwaves off the surface.

NASA launched Seasat in 1978. Although it operated for only three months, its radar altimeter was able to survey 95 percent of the ocean surface with a precision of five to ten centimeters. The newer Geosat altimeter has an improved sensitivity of three to six centimeters—a precision that brought the discovery of hundreds of previously unknown seamounts. When William Haxby of the Lamont-Doherty Geological Observatory produced maps of the marine gravity field from the satellite data, many new rifts, ridges, and fracture zones appeared.

Marine technology has evolved to the point today where we can send people and instruments down to the deepest parts of the world's oceans. To do this safely requires detailed information about the ocean bottom and the geologic forces that shape the ocean basins. Deep-diving submarines and submersibles need to know how to find their positions in an underwater world of perpetual darkness, so precise charts for bottom reference are vital.

Even with advanced space technology the only way to get an accurate bathymetric chart is to send out a survey ship. A map prepared by the National Geophysical Data Center of the National Oceanic and Atmospheric Administration (left, above) shows relief beneath the Caribbean Sea and Atlantic Ocean, including the Mid-Ocean Ridge.



TECHNOLOGIES FOR MAPPING SEAFLOOR: MULTIBEAM ECHO SOUNDER, AT LEFT, AND SIDE-SCAN SONAR, AT RIGHT.

Mapping of the ocean floor is now done with an accuracy thought impossible just a decade ago. We are witnessing an explosion of knowledge about the world's oceans and seas. Each new survey, each new dive of increasingly sophisticated deep submersibles and ROVs reveals information pertinent to matters ranging from continental drift and plate tectonics to commercial fishing and submarine navigation. For lack of the proper tools, this vast undersea frontier has defied exploration until very recently. Now that new technology is at hand, slowly, earth's underwater realm is beginning to emerge.

—REAR ADM. RICHARD F. PITTENGER
Oceanographer of the Navy

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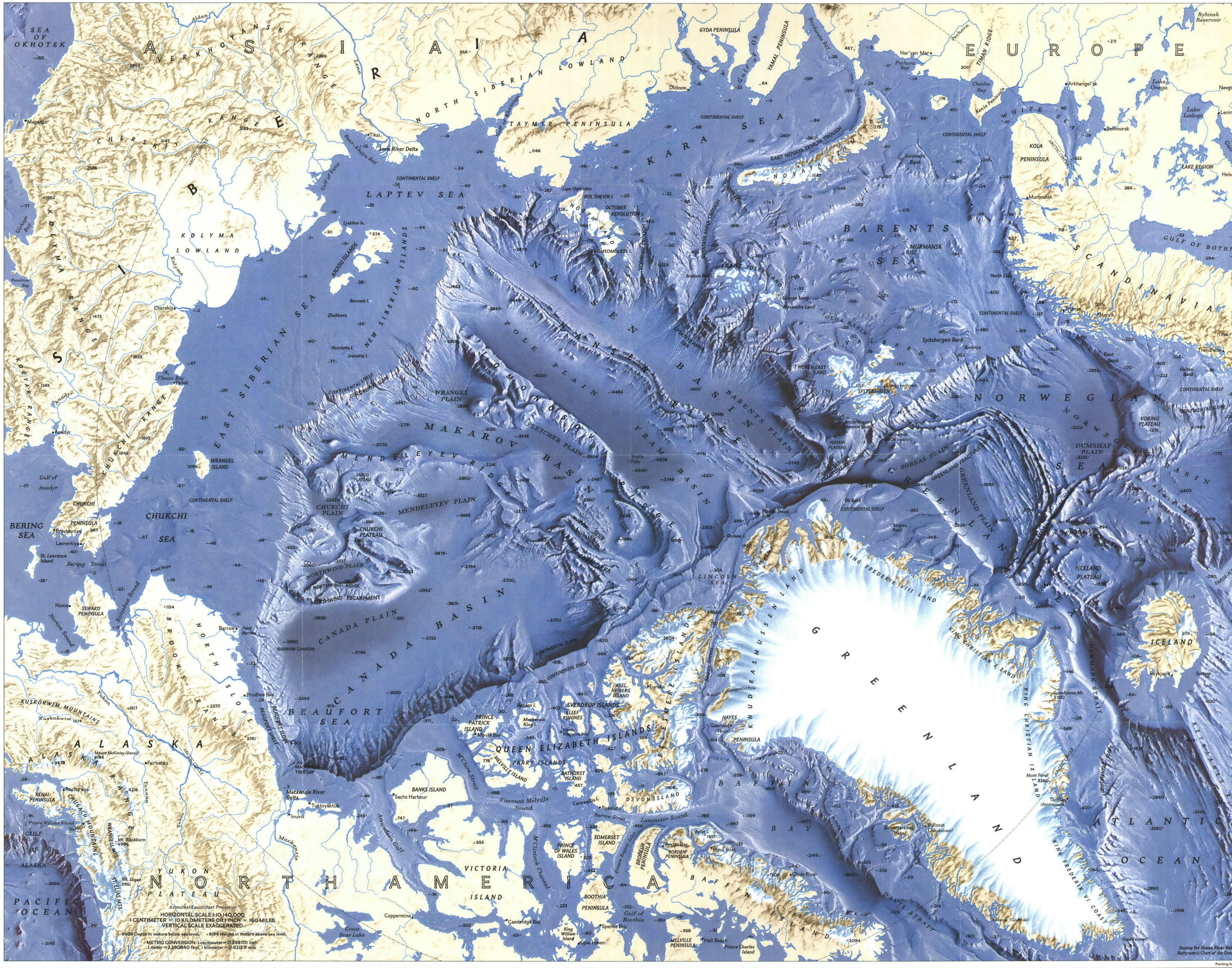

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WILLIAM N. PALMSTROM, CHIEF CARTOGRAPHIC ART DIVISION
Based on the bathymetric studies of Bruce C. Heezen and Marie Tharp
of the Lamont-Doherty Geological Observatory and the U.S. Naval Oceanographic Office.
Painted by Heinz C. Schaefer, assisted by Heinz Vecksel. Compiled by Leo J. Bodenchuk
Azimuthal Equidistant Projection centered on the North Pole
HORIZONTAL SCALE 1:6,000,000 OR 158 MILES TO THE INCH
VERTICAL SCALE EXAGGERATED
STATUTE MILES
KILOMETERS
OCTOBER 1971
SIBERIA
NORTH SIBERIAN LOWLAND
TAYMYR PENINSULA
KARA SEA
NOVAYA ZEMLYA
GYDA PENINSULA
YAMAL PENINSULA
KOLA PENINSULA
LAPTEV SEA
SEVERNAYA ZEMLYA
OCTOBER REVOLUTION I.
BARENTS SEA
FRANZ JOSEF LAND
GEORGE LAND
ALEXANDRA LAND
NORTH EAST LAND
SPITSBERGEN
SVALBARD
SCANDINAVIA
NORTH CAPE
EAST SIBERIAN SEA
DYAKHOV I.
NEW SIBERIAN ISLANDS
NOVOSIBIRSK ISLANDS
CONTINENTAL SHELF
WRANGEL ISLAND
CHUKCHI SEA
CHUKCHI PENINSULA
BERING SEA
ST. LAWRENCE ISLAND
BERING STRAIT
Point Hope
Barrow
Point Barrow
NORTHWIND ESCARPMENT
CANADA ABYSSAL PLAIN
WRANGEL ABYSSAL PLAIN
CHUKCHI PLATEAU
NORTH POLE
POLE ABYSSAL PLAIN
LOMONOSOV RIDGE
FRAM BASIN
GREENLAND SEA
MOHNS RIDGE
KNIPOVICH RIDGE
KOLBEINSEY RIDGE
JAN MAYEN
ICELAND
DENMARK STRAIT
KNUD RASMUSSEN LAND
KING FREDERIK VI LAND
KING CHRISTIAN X LAND
GREENLAND
HAYES PENINSULA
ELLESMERE ISLAND
AXEL HEIBERG ISLAND
BEAUFORT SEA
PRUDHOE BAY
MACKENZIE CONE
PRINCE PATRICK ISLAND
QUEEN ELIZABETH ISLANDS
BANKS ISLAND
VISCOUNT MELVILLE SOUND
CORNWALLIS I.
DEVON ISLAND
BAFFIN BAY
SOMERSET ISLAND
PRINCE OF WALES ISLAND
BYLOT I.
BORDEN PENINSULA
DISKO
VICTORIA ISLAND
BOOTHIA PENINSULA
KING WILLIAM ISLAND
MELVILLE PENINSULA
BAFFIN ISLAND
DAVIS STRAIT
PRINCE CHARLES ISLAND
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ALASKA RANGE
Mount McKinley
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Anchorage
KENAI PENINSULA
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Mt. Blackburn
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19850
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